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(54) Fabricating a compound semiconductor thin film on dielectric thin film

(57) A method for fabricating a defect-free compound semiconductor thin film on a dielectric thin film, involving oxidising multi-semiconductor layers, consisting of a hetero-compound semiconductor thin film (3) made of one of GaAs, InGaAs or InAs over a thin film (2a) containing a carbon impurity of a high concentration and made of AlGaAs series, the oxidations being carried out by annealing with steam, thereby rapidly growing a hetero-semiconductor thin film with no defects over a dielectric thin film made of Al_2O_3.

FIG.1A

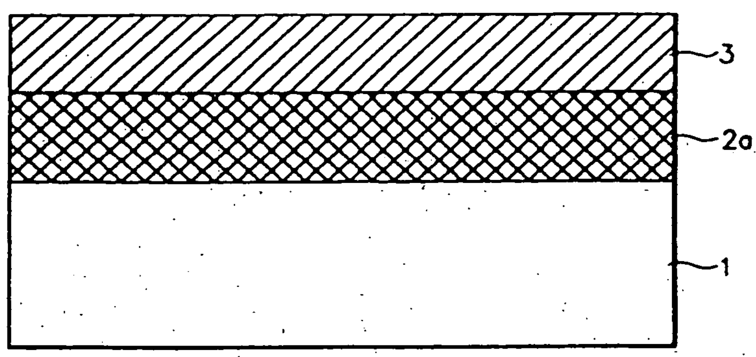

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FIG. 1A

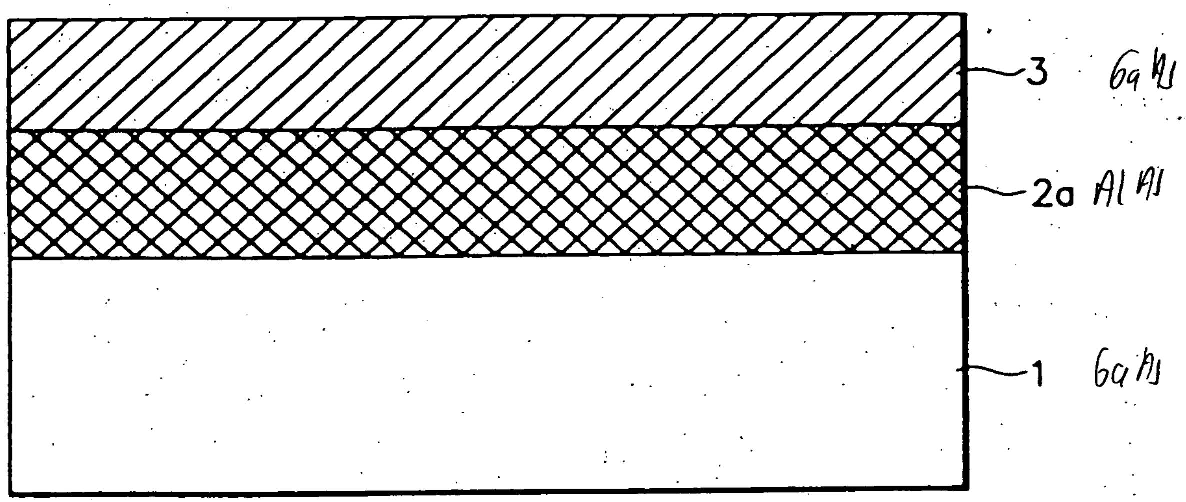
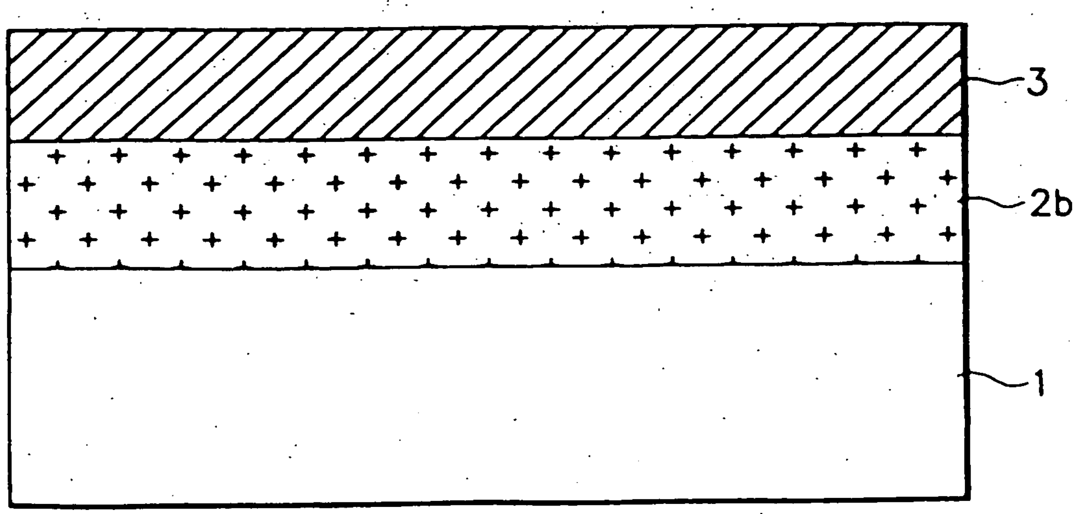


FIG. 1B



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METHOD FOR FABRICATING A COMPOUND SEMICONDUCTOR THIN FILM ON DIELECTRIC THIN FILM

The present invention relates to a method for fabricating a compound semiconductor thin film, having a substantially defect-free semiconductor lattice structure, on a dielectric thin film.

The growth of various semiconductor thin films on an oxide layer has many advantages, such as;

(i) band gap may be freely controlled to improve various characteristics of a resulting device and/or extend the range of the device;

(ii) a device grown over a natural oxide is convenient to process due to the oxide layer;

(iii) semiconductor thin films, such as InGaAs and InAs, with no defects may be grown on a GaAs substrate with a dielectric thin film between the semiconductor thin films and the substrate (this may allow compound semiconductors of a new concept, such as a semiconductor on insulator (SOI) and a metal oxide semiconductor field effect transistor (MOSFET), to be produced); and

(iv) a device having a 3-dimensional current blocking layer and a new-type of distributed Bragg reflector including an oxide can be fabricated using an oxide pattern etching method and a regrowth.

A previously proposed method for growing a semiconductor thin film over an oxide first anneals a surface of high purity AlAs-AlGaAs-GaAs thin film with the AlAs-AlGaAs-GaAs directly in contact with a vapour for about 3 hours so as to form an oxide layer.

This technique has the disadvantages that the oxidation rate of the high purity AlAs thin film is very slow (the process taking approximately 3 hours), and the GaAs thin film is also oxidized during the annealing thereby changing its quality.

The present invention addresses the above problems and seeks to provide a method for fabricating a compound semiconductor thin film which is capable of growing a defect-free GaAs epitaxial film on a dielectric thin film and growing various semiconductor thin films on an oxide layer.

Viewed from one aspect the invention provides a method of fabricating a substantially defect-free compound semiconductor thin

film on a dielectric thin film comprising the steps of:

(i) growing a thin film of AlGaAs series containing carbon impurities on a GaAs substrate;

(ii) growing a hetero-compound semiconductor thin film made of one of GaAs, InGaAs or InAs on the thin film of AlGaAs series, thereby forming multi-semiconductor layers; and

(iii) oxidizing the multi-semiconductor layers by annealing in an oxidizing atmosphere, thereby forming a compound semiconductor thin film on a dielectric thin film.

In at least some embodiments there is provided a method for fabricating a defect-free compound semiconductor thin film on a dielectric thin film which oxidizes multi-semiconductor layers consisting of a hetero-compound semiconductor thin film made of one of GaAs, InGaAs or InAs over a thin film containing carbon impurities of a high concentration and made of AlGaAs series by an annealing at a vapour ambient.

Viewed from another aspect the invention provides a method of fabricating a dielectric thin film for use with a compound semiconductor thin film comprising growing a thin film of $Al_xGa_{1-x}As$ (where $0 \le x \le 1$) containing carbon impurities and oxidizing said thin film of $Al_xGa_{1-x}As$ to form said dielectric thin film.

Viewed from a further aspect the invention provides a compound semiconductor thin film device having a dielectric thin film comprising Al_2O_3 with carbon impurities.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1A is a sectional view of a configuration of multi-thin film layers after an epitaxy growth process; and

Figure 1B is a sectional view of a configuration of a multi-thin film layer after an oxidation process.

Referring to Figures 1A and 1B there are shown sectional views illustrating a method for fabricating a defect-free compound semiconductor thin film on a dielectric thin film in accordance with one embodiment of the present invention.

In accordance with this method, an $Al_xGa_{1-x}As$ thin film which is highly doped with carbon impurities in a concentration above 2×10^{20}

cm^{-3} is first grown over a GaAs substrate and subsequently a GaAs cap layer having the same lattice constant as the GaAs substrate is grown to a thickness of 20 nm.

Figure 1A shows a structure of multi-thin film layers in the case where the Al content x of said $Al_xGa_{1-x}As$ thin film is 1, thus yielding AlAs.

In Figure 1A, the reference numeral 1 designates a GaAs substrate, the reference numeral 2a designates an AlAs layer containing carbon impurities of a high concentration, and reference numeral 3 designates a thin GaAs cap layer.

An InGaAs thin film, which has a lattice constant different from the GaAs substrate may be substituted for GaAs as the cap layer 3, this InGaAs thin film being grown below a critical thickness.

Next, the grown thin film is mounted in an electric furnace and is subjected to a natural oxidation process by flowing nitrogen gas mixed with a vapour (water vapour/steam) to the electric furnace at a temperature of 400C for about 5 minutes. Under these conditions, the larger the Al content x, the faster the oxidation rate.

After the natural oxidation process, the AlAs layer is changed into an amorphous Al_2O_3 layer which is transparent with respect to visible light.

Because the oxidation speed of the GaAs thin films serving as the substrate and as the cap layer is very slow, oxide formation of the GaAs layer is negligible during this natural oxidation. Furthermore, only the surface of the GaAs thin film exposed to the gases is slightly oxidized.

Figure 1B shows a changed thin film structure of Figure 1A after oxidation. Referring to the drawings, the AlAs layer 2a is changed into the stable amorphous Al_2O_3 layer 2b and the two GaAs layers 1 and 3 remain with substantially no oxidation.

One way of viewing the natural oxidation process is that oxygen within the water molecules pass through the GaAs layer 3 serving as the cap layer and abruptly react with the C_{AS} in the AlAs layer 2a, thereby being substituted for As and then being combined with Al which is connected to the neighbour C_{AS}.

After formation of such a nuclear site, oxygen becomes

consistently substituted for the neighbouring As, thereby causing the AlAs layer 2a to be oxidized. The number of nuclear sites is controlled by the amount of carbon atoms, these carbon atoms being uniformly distributed. Therefore, the AlAs layer 2a is rapidly oxidized and the created oxide film made of Al_2O_3 is very stable. A characteristic of the created oxide film is that it is a dielectric which is very different from the AlAs layer.

In contrast to the above, an AlAs layer undoped with carbon impurities has a very slow oxidation speed.

The upper surface of the GaAs cap layer 3, which has a negligibly slow oxidation speed, is also exposed to the vapour so a small number of atomic layers are oxidized. However, most of the GaAs cap layer 3 maintains its own lattice state. The oxidized portion of the GaAs cap layer 3 may be removed by a reagent and then a new GaAs layer grown as the cap layer to a desired thickness.

Also in cases where an InAs thin film, which has an even slower oxidation speed than the GaAs layer, serves as the cap layer, this is grown on the AlAs layer 2a with an InAs thin film growth method. Thereafter, the AlAs is changed into Al_2O_3 in the same manner as for the GaAs layer as a cap layer.

Although the lattice mismatching between the AlAs and InAs layers is large, because the InAs thin film layer is formed on an amorphous Al_2O_3 layer after the oxidation process, strain due to mismatching doesn't exist in the finished multi-semiconductor thin film layers. Accordingly, after the oxidized portion of the InAs layer is removed by a reagent, although a thick new InAs layer may be grown by an epitaxy growth method, a defect-free lattice layer nature can be maintained.

When an AlAs or AlGaAs thin film containing carbon impurities of a high concentration is annealed in an oxidising atmosphere, the oxidation speed of the thin film is approximately 20 times faster than the technique with an AlAs layer with no carbon impurities. Therefore, although the GaAs layer is already grown on the AlAs layer or the AlGaAs layer, only the AlAs layer or the AlGaAs layer is oxidized.

According to the described technique, a defect free GaAs thin film layer as well as a defect free InGaAs layer of a hetero junction thin film having a large lattice mismatch with the GaAs substrate layer

can be grown on an Al_2O_3 layer of a dielectric material.

This method for growing various compound semiconductor thin films on a dielectric thin film overcomes some restrictions of the present band gap technology and allows the creation of devices of a new concept. Oxide formation technology for compound semiconductors may pave the way for the development of new compound semiconductor technology analogous to that that is possible in silicon technology.

Although the preferred embodiments of the invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope of the invention as set out in the accompanying claims.

CLAIMS

1. A method of fabricating a substantially defect-free compound semiconductor thin film on a dielectric thin film comprising the steps of:

(i) growing a thin film of AlGaAs series containing carbon impurities on a GaAs substrate;

(ii) growing a hetero-compound semiconductor thin film made of one of GaAs, InGaAs or InAs on the thin film of AlGaAs series of thereby forming multi-semiconductor layers; and

(iii) oxidizing the multi-semiconductor layers by annealing in an oxidizing atmosphere, thereby forming a compound semiconductor thin film on a dielectric thin film.

2. A method as claimed in claim 1, wherein the thin film of AlGaAs series is doped with carbon impurities in a concentration of over $2 \times 10^{20} cm^{-3}$ and the dielectric thin film is said thin film of AlGaAs series fast oxidized starting from one or more nuclear sites.

3. The method as claimed in any one of claims 1 or 2, wherein the oxidation annealing is carried by flowing nitrogen gas mixed with steam at a temperature of substantially 400C over the multi-semiconductor layers for 5 minutes, thereby naturally oxidizing said thin film of AlGaAs series.

4. A method of fabricating a dielectric thin film for use with a compound semiconductor thin film comprising growing a thin film of $Al_xGa_{1-x}As$ (where $0 \le x \le 1$) containing carbon impurities and oxidizing said thin film of $Al_xGa_{1-x}As$ to form said dielectric thin film.

5. A compound semiconductor thin film device having a dielectric thin film comprising Al_2O_3 with carbon impurities.

6. A method of fabricating a substantially defect-free compound semiconductor thin film on a dielectric thin film substantially as hereinbefore described with reference to the accompanying drawings.

7. A compound semiconductor thin film device substantially as hereinbefore described with reference to the accompanying drawings.

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Patents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report)**	Application number GB 9424423.3
Relevant Technical Fields (i) UK Cl (Ed.N) H1K - KJACX, KLHA, KLHX (ii) Int Cl (Ed.6) H01L	Search Examiner S J DAVIES Date of completion of Search 28 FEBRUARY 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE WPI	Documents considered relevant following a search in respect of Claims :- ALL

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A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
A	WO 80/00521 A1	(WESTERN ELECTRIC) see eg page 4, lines 10-34	
A	US 5254397	(LIN ET AL) see eg column 4, line 36 - column 5, line 37	

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